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Concept, Architecture, and Design of a Stand-Alone Physics-Based Simulation Capability to Support Maritime-Air Littoral Tactics Development

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Abstract

The Maritime Air Littoral Operations (MALO) Technology Demonstration Program (TDP) was undertaken by the Future Forces Synthetic Environment (FFSE) at Defence Research and Development Canada (DRDC) Ottawa to develop a modeling and simulation (M&S) based experimental environment to support the development and evaluation of maritime air operational tactics, doctrine and new concepts.

A prototype for a Stand-Alone Physics-based Simulation Capability, termed the Synthetic Environment Research (SER) workstation, was designed in Phase one of the MALO TDP. The prototype was designed to support rapid experimentation within pre-configured operational scenarios and tactics alternatives, and to be employed by personnel at the CF Maritime Warfare Center during the early stages of concept development and experimentation. The SER consists of a Commercial-Off-The-Shelf (COTS) tool, the Satellite Took Kit from Analytical Graphics Inc., embedded within a MALO – specific user application layer and interface that leads the operator through the experimental process of modifying tactic variables, running and re-running a simulation, visualizing the scenario execution, and viewing data on programmed metrics.

Résumé

La section des Environnements Synthétiques des Futures Forces (ESFF), à Recherche et Développement pour la Défense Canada (RDDC) à Ottawa s’est vue attribuer le Programme de Démonstration de Technologies (PDT) Operations Maritimes-Aériennes Côtières (OMAC). L’objectif premier de ce projet est de concevoir et de développer un environnement d’expérimentations basé sur la Modélisation et la Simulation (M&S) afin de supporter le développent ainsi que l’évaluation de tactiques opérationnelles pour les plateformes maritimes aériennes sur le littoral, le développement de doctrines, et finalement l’exploration de concepts émergents.

Un prototype d’une application de simulation non-distribuée et intégrant les caractéristiques physiques, appelé station de travail de l’Environnement de Recherche Synthétique (ERS), a été conçu et bâti durant la première phase du PDT MALO. Le prototype était conçu pour supporter les expérimentations rapides pour des scenarios opérationnels préconfigurés et le développement de tactiques; Ce système devrait être opéré par des operateurs du Centre de Guerre Navale des Forces Canadiennes (CGNFC) durant les phases préliminaires de développement de concepts et leurs expérimentations. Le ERS combine un outil commercial, Satellite Tool Kit de Analytical Graphics Inc., imbrique avec une application spécifiquement développée pour OMAC, qui fournit une interface utilisateur pour diriger l’utilisateur dans le processus expérimental de construction de scenarios d’intérêt, de modifications des variables des tactiques, pour l‘exécution de la simulation, la visualisation des scenarios, ainsi que la production des données pour les métriques programmées.

Executive Summary

The Maritime Air Littoral Operations (MALO) Technology Demonstration Program (TDP) was undertaken by the Future Forces Synthetic Environment (FFSE) at Defence Research and Development Canada (DRDC) Ottawa to develop a modeling and simulation (M&S) based experimental environment to support the development and evaluation of maritime air operational tactics, doctrine and new concepts.

The MALO team conceived an environment consisting of two technologies for simulation environments thus forming two distinct M&S capabilities. Both systems serve the same technical objectives but with a significant difference in the level of fidelity of the physical entities and their behaviour, as well as the way the systems are utilized by the operators. These systems are to be developed in an incremental process of four phases, with demonstration at each phase, and final delivery to the MALO TDP client's site, the Canadian Forces Maritime Warfare Centre (CFMWC). The two main deliverable simulation systems are:

- A stand alone Synthetic Environment Research (SER) workstation, to support rapid experimentations within pre-configured operational scenarios and tactics alternatives. This system is to be built, demonstrated and delivered to the client during the first phase of the project;

- The MALO Synthetic Environment Analysis System (MSEAS), a much more capable M&S based experimental environment that will support stand alone and distributed experimentation based on the High Level Architecture (HLA) protocol. The MSEAS is envisaged to be primarily a real-time system with man-in-the-loop operator(s), reactive Computer Generated Forces (CGF) and a supporting suite of tools to build scenarios and collect and analyse data. The building of this system will require three iterations of an incremental process, starting with low fidelity models, re-using some of the SER models, then upgrading these models to high fidelity models and man-in-the-loop simulators where necessary, and finally adding the MSEAS analytical layer on top of the core simulation system. This will allow for maximum reuse of the assets built in the previous iterations, and will provide a functioning system at each phase.

The present approach of using two technologies within one single experimentation process is believed to be the first in its kind, at least in Canada. The subject of this report is a detailed description of the first system (the SER), its objectives, rationale, architecture and design.

We also discuss how we foresee the role of the SER system within the Concepts Development and Experimentations (CD&E) program of the CFMWC, which should also pertain to any warfare experimentation centre overall objectives and strategies.

Hassaïne, F., Vallerand, A., Hubbard, P. Concept, Architecture, and Design of a Stand-Alone Physics-Based Simulation Capability to Support Maritime-Air Littoral Operations. DRDC Ottawa TR 2005-229. Defence R&D Canada – Ottawa.

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La section des Environnements Synthétiques des Futures Forces (FFSE), à Recherche et Développement pour la Défense Canada (RDDC) à Ottawa s'est vue attribuer le Programme de Démonstration de Technologies (PDT) Operations Maritimes-Aériennes Côtières (OMAC). L'objectif premier de ce projet est de concevoir et de développer un environnement d'expérimentations basé sur la Modélisation et la Simulation (M&S) afin de supporter le développent ainsi que l'évaluation de tactiques opérationnelles pour les plateformes maritimes aériennes sur le littoral, le développement de doctrines, et finalement l'exploration de concepts émergents.

L'équipe du projet OMAC a conçu un environnement de simulation à deux échelons, comprenant deux capacités de M&S. Ces deux systèmes servent essentiellement les mêmes objectifs techniques avec cependant une différence notable dans le niveau de représentation des entités physiques, de leurs comportements, ainsi que dans la façon dans laquelle les systèmes sont utilisés par les operateurs. Ces systèmes doivent être développés selon un processus incrémental de quatre phases, avec démonstration a chaque phase, et livraison au site du client du PDT, le Centre de Guerre Navale des Forces Canadiennes (CGNFC). Ces deux systèmes sont :

- Un environnement synthétique basé sur un système individuel d'une station de travail, pour supporter des expérimentations rapides, avec des scénarios déjà bâtis et configurés et une série de tactiques préalablement programmées; Ce système est l'objet de la première phase et devrait être délivré au CGNFC a la fin de la phase une;

- Le System d'Analyse de l'Environnement Synthétique de OMAC (SAESO), un environnement d'expérimentations basé sur la M&S, qui offre beaucoup plus de potentiel que le premier système, et qui supportera des expérimentations en mode individuel ou en mode distribué, basé sur le protocole High Level Architecture (HLA). Cette capacité de M&S est conçue principalement pour être un système temps-réel avec Operateur dans la boucle, des éléments réactifs, ce qui présuppose des Forces Générées par Ordinateur (FGO), ainsi qu'une suite d'outils pour supporter la construction de scenarios, la collecte des données de simulations et leur analyse. La construction d'une telle capacité requiert trois itérations d'un processus incrémental, commençant avec certains des éléments du système individuel qui sont de basse fidélité, puis l'augmentation du niveau de fidélité de ces éléments, et finalement l'ajout d'une couche au dessus du système de simulation central, qui sera le SAECO. Cela permettra d'une part le maximum de réutilisabilité des éléments bâtis dans les itérations précédentes, et d'autre part d'avoir un système fonctionnel à chaque phase.

Cette approche des deux capacités combinées au sein du même processus expérimental est unique dans son genre, et sera élaborée plus en détail dans un rapport à venir. Le sujet premier de ce rapport étant la discussion du premier système, son objectif global, son architecture ainsi que sa conception.

Nous expliquerons également comment nous pensons le rôle du Système Individuel dans le programme de Développement de Concepts et les Expérimentations du client du PDT, le CGMFC, un rôle qui devrait en principe relever des objectifs globaux et des stratégies de tout centre d'expérimentation de guerre.

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1. Introduction

This section introduces the MALO TDP through its history and objectives. The end-user of the systems developed in the MALO TDP is the Maritime Air operational community. We provide a description of this community, their role and assets, as well as a vision of how MALO Modeling and Simulation (M&S) technologies can assist them achieve their objectives. At the end of the section we will give a list of MALO mandatory and recommended documents.

1.1 The MALO TDP

The Maritime Air Littoral Operations (MALO) Technology Demonstration (TD) project was established to perform research and develop an M&S based capability, with scope focused on the Maritime Air component of maritime operations, and limited to the evaluation of a subset of tactics studies to be mutually agreed with the project sponsors in the Maritime Air community. The MALO TDP has a long history. An initial attempt at the MALO TDP was initiated in September 2002, but failed due to the availability and maturity of R&D simulation systems at DRDC labs and in industry and the resulting difficulty in integrating systems into a single system useful to the user community.

A revamped formulation of the MALO TDP project was formally approved with a new Project Charter (PC) and a new Project Implementation Plan (PIP) [2] in March 2005 leading to a 2008 completion date, with the Future Forces Synthetic Environment (FFSE), at Defence Research and Development Canada (DRDC) as the Lead lab. Fundamentally, FFSE's experimentation will test the hypothesis that M&S can be used to develop and assess tactics and doctrine for Maritime Air Littoral Operations. CFMWC is the Client and Maritime Air Component Atlantic [MAC(A)] is the project sponsor.

Under the leadership of FFSE, the MALO TDP was reorganized according to a spiral development and evaluation process, with four phases and specific experiments to be demonstrated and conducted in each phase, which include:

- A stand alone Synthetic Environment Research (SER) workstation, delivered early in the project to the Canadian Forces Maritime Warfare Centre (CFMWC), able to support rapid experimentation within pre-configured operational scenarios and tactics alternatives;

- A low fidelity simulation environment based on the High Level Architecture (HLA, see the reference documents [5] and [6] for the specifications of the two main standards) to support the development and experimentation of the selected maritime air scenarios (or a subset of them), and to evaluate alternative tactics;

- A higher fidelity HLA-based simulation environment to support the development and experimentation of the same scenarios and tactics but with greater level of detail and models with higher resolution and fidelity;

- And finally, the MALO Synthetic Environment Analysis System (MSEAS), a more capable analytical M&S based experimental environment that will support stand alone and distributed experimentations within the CFMWC community.

1.2 The Maritime Air Context

The Maritime Air operational community is comprised of a *maritime* component, which includes the various ship classes in the maritime fleet, and an *air* component which includes the CP140 Aurora aircraft fleet and the Maritime Helicopter aircraft fleet. In combination, the Maritime Air community manages sub-surface, surface, and air operations within the maritime domain. The maritime domain includes *blue water* or deep ocean operations, as well as *brown water* or littoral operations close to shore.

The Canadian Forces Maritime Warfare Centre (CFMWC) has the responsibility to conduct Concept Development and Experimentation (CD&E) related to alternative maritime concepts, which includes alternative maritime air concepts. The CD&E process involves the investigation of:

- Alternative Doctrine

- Alternative Tactics, Techniques, and Procedures

- Alternative Technologies & Systems and their impact on operational performance and changes in required tactics to fully take advantage of them.

Ideas for new technologies, tactics, or doctrine can come from a variety of sources including the full range of operational units, headquarters units, acquisition teams, R&D units, and the CFMWC itself. The annual work plan of the CFMWC requires a constant selection and prioritization of the CD&E experiments to be conducted in the annual experimental campaign, with detailed plans being developed for each study series. Experiments have historically been conducted using live simulation in workshops or live trials using the real platforms and systems. These are important methods for experimentation, but can be costly and difficult to schedule. As a result, it is desirable to increasingly use constructive simulation whereby all entities are simulated through computer models and virtual simulation whereby Human-in-the-Loop (HITL) simulation devices are integrated with constructive simulation in synthetic environments. Constructive and virtual M&S capability will enable the CFMWC to rapidly and incrementally study alternative concepts, with a process that starts with early constructive studies followed by virtual simulation studies (stand alone or distributed) followed by live simulation studies conducted as and when required.

The Maritime community is in the process of introducing a range of new technologies and systems into the operational capability. Sample technologies and systems include the planned introduction of the:

- Tactical Integrated Active/Passive Sonar (TIAPS),
- SSQ 110 Explosive Echo-Ranging (EER) Sonobuoy,
- CP140 Aurora Incremental Modernization Project (AIMP) which includes a wide range of improved mission system capabilities,
- Maritime Helicopter replacement of the Sea King fleet,
- Victoria Class submarine,
- Upgraded Canadian Patrol Frigate.

In 1997, a review of Research and Development (R&D) projects by the staff of the Canadian Forces Director of Air Requirements (DAR 3) highlighted that the above list of planned technologies resulted in a planned increase in capability for which tactics and doctrine were not fully developed.

In addition, it was noted that while the Maritime Surface and Maritime Air communities had extensive experience operating in blue water undersea warfare environments, these planned new capabilities, and a shift in operational focus to littoral environments, would require research and development of shallow water tactics and doctrine.

The research, development, and delivery of an M&S based tactics evaluation environment were identified as an important evolution to the maritime CD&E capability, and as an important enabler to the evolving CFMWC community.

1.3 This Document

This document provides a description of the overall concept, the architecture, as well as the underlying design used for the development of a prototype of the Stand-Alone Physics-based Simulation Capability, which constitutes the deliverable for phase one of the TDP[1]. A very concise presentation of the future MALO HLA system (to be delivered in phase four) is also provided, in order for the reader to comprehend conceptually the main objectives, roles as well as the differences between the two systems, and the underlying arguments for the incremental approach in the execution of the project.

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[1] The documented SER Workstation design was a MALO TD Phase 1 deliverable, within Gate 1 of the project (October 2005).

This document also attempts to foresee the role of the SER capability within the CFMWC, mainly in their Concepts Development and Experimentation (CD&E) activity program. A precise workflow process is then provided, which describe in detail the utilization process of the SER system, for both a CD&E operator (typically a CFMWC personnel), or a scientist from DRDC.

Phase 1 of the project required that the SER Workstation be designed, developed, and demonstrated. Early work in that process required the definition of requirements for the SER Workstation, and the documentation of the architecture and design. This design work has occurred, with architecture and design documentation contained herein.

1.4 Guidance References

Guidance references include documents that provide additional guidance to the work reported on within this document, and/or general project information that may help the reader fully understand the project context related to this document.

- A Practical Guide for Developing and Writing Military Concepts [1]
- MALO Project Implementation Plan (PIP) [2]
- Satellite Tool Kit User Manual [3]

2. M&S Support to CD&E – Key Concepts for MALO

This section outlines some key concepts that have been established by the MALO project for M&S support to Maritime Air CD&E. The high level requirements and design descriptions for both the SER and MSEAS M&S environments have been derived from these concepts, and therefore the material has been repeated here to provide the background context for the SER Workstation Architecture and Design.

2.1 Maritime Operations

Maritime operations within the Canadian Navy include sub-surface, surface, and air operations conducted alone but more typically in combination within the context of a naval task group. The Canadian capability often operates within US Battle Groups, and/or Multinational Interdiction Forces.

Canadian sub-surface assets include:

- The Victoria Class Long Range Patrol Submarine (SSK)

Canadian surface assets include:

- The Halifax Class Multi-Role Patrol Frigate (FFH)
- The Iroquois Class Area Air Defence Destroyer (DDG)
- The Protecteur Class Auxiliary Oil Replenishment (AOR)
- The Kingston Class Coastal Defence Vessel (MM)

Canadian maritime air assets include:

- CH-124 Sea King Anti-Submarine Warfare Helicopter
- CP-140 Aurora Strategic Airborne Surface Surveillance Aircraft

These assets provide maritime support across the full range of Canadian Forces missions, as defined by the range of possible scenarios in the Department of National Defence (DND) Force Planning Scenarios (FPS). These scenarios, and the maritime component within them, result in Open Ocean, or blue water scenarios, often comprised of anti-submarine warfare and general task group protection; as well as brown water or littoral scenarios which include a range of missions involving surveillance, interdiction, and protection of coastal waters.

2.2 Concept Development and Experimentation

Concept Development & Experimentation (CD&E) is a process by which new or alternative operational concepts are evaluated often resulting in recommendations that may guide the development or modification of military doctrine or tactics, or that may guide the requirements for acquisition of new technologies.

To be clear on the role of CD&E, a series of definitions are outlined below that illustrate the hierarchical relationships from platforms and systems up to military concepts:

1. Platforms, Systems, and Technologies
   These terms refer to the weapons platforms, sensor and weapon systems, and associated technologies used by military forces. These technologies are research and developed, built by a range of defense companies, acquired by military acquisition teams, and deployed by military units throughout their life cycle.

2. Tactics
   Tactics are the branch of military science dealing with detailed maneuvers to achieve objectives set by strategy. Tactics are the prescribed behavior that results in the ordered arrangement and maneuver of units in relation to each other and/or to the enemy in order to use their full potentialities. Military platforms or systems are applied using tactics, to achieve objectives.

3. Doctrine
   Doctrine is defined as the fundamental principles by which the military forces or elements thereof guide their actions in support of national objectives. Tactics are developed in support of established doctrine.

4. Concept
   A military concept has been defined, by Schmitt, as “a description of a method or scheme for employing specified military capabilities in the achievement of a stated objective or aim [1]”. Schmitt [1] also incorporates a temporal aspect, defining *historical* concepts, *current* concepts and *future* concepts:

   - Current concepts are defined as applied today with today’s organizational structures, tactics and technologies whereas future concepts remain untested and are therefore the subject of experimentation.
   - Current concepts, once tested, approved and promulgated by proper authority become doctrine.
   - Current and future concepts are subject to evolution over time under the influence of technological, societal, political, economic and environmental developments as well as the influence of other concepts themselves. With this evolution, future concepts eventually could become current concepts which in turn could form doctrine.

The CD&E process is therefore interested in evaluating alternative technologies, and alternative tactics, formed as concepts, resulting in guidance and recommendation of concepts that the military should implement, which will therefore shape doctrine.

2.3 The CF Maritime Warfare Centre

The CFMWC has at its disposal:

- Live platforms and systems, and the personnel to staff them, from which live simulation exercises, or field trials can be conducted.

- A simulation centre, where constructive and virtual simulation devices can be housed and used in the experimental process.

The CFMWC personnel include:

- Maritime operational personnel, typically military officers, who are posted to the CFMWC to conduct CD&E.
- Contracted support personnel, which can include computer system support.

The extended CFMWC community can include a range of personnel involved in the CD&E process, including:

- Defence R&D Canada research personnel, who may have developed new technologies for evaluation, who may have models or simulations of maritime technologies, and who may have expertise in areas relevant to the CD&E process.
- Military units who may have virtual simulation devices that could be networked into CD&E experiments.
- Military units who operate platforms used in live simulation experiments.
- Coalition, Joint, Land and Air Warfare Centres, who may be required to collaborate in joint simulation exercises in support of CD&E (constructive, virtual, or live simulation based exercises).

All CD&E activities involve the use of simulation, including:

1. <u>Constructive simulation</u>, whereby all platforms, technologies, and tactics are modeled using the computer and simulations of various scenarios are used to evaluate and compare operational impacts of alternative concepts.
2. <u>Virtual simulation</u>, whereby human-in-the-loop simulation devices are integrated with constructive simulation in synthetic environments, with some entities and their tactics modeled within the computing environment, and other tactics and behaviours played out in real time by the humans operating the virtual simulation devices.
3. <u>Live simulation</u>, whereby the real crews operate the real systems and platforms in mock scenarios.

The relative utility of each of these simulation methods, and the level of fidelity required using any one method, is dependent on the phase of analysis and experimental objectives.

It is felt that an iterative experimentation approach is warranted for the incremental evaluation of proposed changes to technologies or tactics. In this approach, incremental stages of experimentation might include:

- Constructive simulation experiments using low to medium fidelity models, across a range of scenarios, should be conducted to rapidly evaluate a proposed tactic or technology.

- Improved fidelity models or synthetic environments, integrated using HLA protocols, could be used to conduct more accurate assessments where warranted (*e.g.* impact of a specific sensor technology proposal on low level tactics and associated performance).
- Integrated HITL virtual simulation devices should be networked into simulation environments using HLA protocols to support higher fidelity evaluation of the impact of alternative tactics or technologies on human decision making or performance (*e.g.* when Target Classification tasks, or decision making tasks, must be evaluated).
- Live simulation experiments should be conducted once a tactic or technology has been proven incrementally through the other methods of simulation, to focus the expenditure of live trials only where required, and to ensure that new concepts are validated through live trials prior to becoming doctrine.

2.4 Conceptual Design of M&S Support to Maritime CD&E

The CFMWC community is mostly operated by military operational personnel posted to the CFMWC on a typical 2-4 year cycle. Depending on activities, there may or may not be additional technical support personnel available in the CFMWC, at times available through civilian support contracts.

To date, M&S technology has required extensive technical skill to configure synthetic environments, develop models, configure and run scenarios, and to extract data to analyze the results of those scenarios. The creation of distributed simulation environments, with multiple constructive and virtual simulation assets integrated, has required even higher levels of skill and teams of personnel.

The MALO project is focused on attempting to provide M&S support technologies to the CFMWC that may permit the typical CFMWC staff member to configure and conduct experiments, with a reduced requirement for contracted technical support each time an experiment needs to be conducted.

There are a number of aspects of a constructive, or constructive/virtual simulation environment that must be configured and operated in order to conduct an M&S based CD&E process. Key elements include:

1. <u>Environment Configuration</u>
   whereby the physical environment where a scenario will be executed (land, air, ocean) must be imported/created/configured for a given scenario or experimental series.
2. <u>Scenario Configuration</u>
   whereby the overall scenario, and associated sequence of events, must be configured and controlled during the conduct of the experiment.
3. <u>Platform/System Configuration</u>
   whereby vehicular platforms (*e.g.* ships, aircrafts) must be modeled, along with their component systems such as sensors and weapon systems.

4. Tactic Configuration
   whereby the behaviour of a platform/system under operational conditions must be modeled and configured (when using constructive simulation and the behaviour must be driven by the computer).

5. Distributed Simulation Configuration
   whereby the simulation operator can more easily configure physical networks, HLA protocol based communication amongst simulations across those physical networks, and monitor these configurations throughout simulation execution.

6. Simulation Run-Time Execution
   whereby the simulation is executed, and visualized, allowing the analyst to observe the execution of the scenario.

7. Data Capture and Analysis
   whereby the analyst can either observe some measures being displayed in real time during simulation execution, and/or appropriate data capture, logging, and analysis tools are available to support post simulation run analysis of the pre-established metrics.

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3. A Synthetic Environment Research Test Bed for Maritime CD&E

3.1 SER Workstation Rational, Concept and Objectives

Existing M&S software technologies can be adapted to provide easy-to-operate user interfaces to support basic CD&E activities associated with modifying established tactics and rapidly conducting experiments to compare alternative variations. From an operational user's perspective this should be accomplished without the need for extensive Software Engineering or M&S application skills each time an experiment needs to be conducted.

The objective of the SER Workstation is to provide a synthetic environment capability whereby an expert user can configure missions, scenarios, systems, and metrics, after which a CFMWC operational user can easily modify tactic variables, run and re-run the simulation, and view data on the programmed metrics, thereby rapidly conducting M&S based CD&E on tactic alternatives. There are tremendous opportunities in being able to bring the power of M&S into the hands of the operational user who will then guide, with agility, future experimentation. It is also worthwhile to highlight that the integrated visualization capability of the SER has a significant impact on the situational awareness perspective of the battlefield, particularly if the M&S environment is integrated from space assets to sub-surface assets and if it has fit-for-the purpose validity, *i.e.* credibility.

Following the rapid assessment process of tactics, with the SER workstation, the selected tactics can then be investigated in a higher fidelity, and with greater resolution in an HLA-based simulation environment, to be developed incrementally during phase 2 to 4 of the TDP.

Figure 1 illustrates the conceptual difference between the MSEAS and the SER. Whereas in SER everything is scripted (the behavior mainly), HLA technology combined with Computer Generated Forces (CGF) allows for the simulation in a distributed environment of systems with a high level of complexity and supports also the interactions between these systems as in the real life (if a dipping sonar pings, then a submarine's sonar could detect it, etc). HLA also allows for simulations/simulators to run in real-time, which can permits the injection of operators' decisions (*i.e.* Human in the loop (HITL)), which is technically a very complicated thing to model. Further, SER and MSEAS level of fidelity and resolution differ greatly, with one CPU being available in the non Real time SER, quite possibly a large number of CPUs come into play into the real time HLA technologies, allowing for the almost infinite improvement of the models fidelity.

Another important feature of the SER is the Monte-Carlo capability, which will allow for the execution of several (tens, hundreds, thousands, etc.) variations of the same scripted scenario through the change of one or several parameters. Without this capability, the validation of a given tactic could be fairly questioned. Taking benefit

of this capability would on the other hand provide the required statistical significance [4] that will support the validation of the used tactic(s).

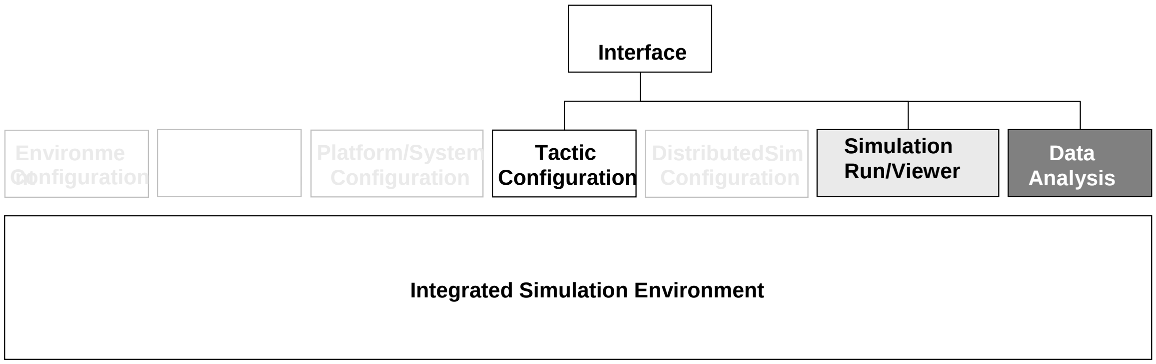

Figure 1: High Level SER Workstation Concept

3.2 The MSEAS Concept

The MSEAS will be the final deliverable of the MALO project. The MSEAS concept provides a range of easy to operate tools for the CFMWC to execute each of the elements outlined in the previous section.

Figure 2 illustrates the concept whereby a single operator has a suite of configuration, execution monitoring, and data analysis tools available at his/her disposal to easily configure environments, scenarios, platform/system models, and tactics to support the CD&E process. It is suggested that these tools could be used in a stand-alone mode of operation, or in a distributed mode of operation whereby physical network tools, and HLA configuration tools are invoked to support rapid configuration of appropriate simulation environments.

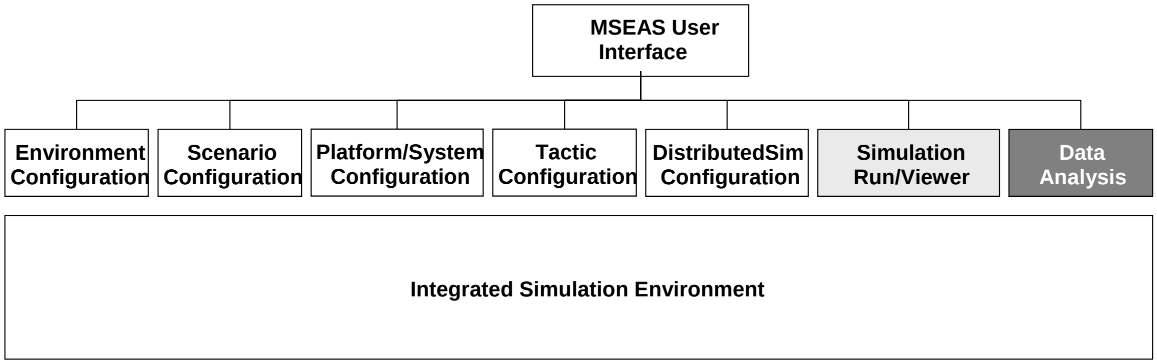

Figure 2: High Level MSEAS System

3.3 SER Workstation Conceptual Design

The SER workstation conceptual design included the following characteristics of the system:

- A stand alone computer workstation, with at least a single monitor, keyboard, and mouse.

- A customized user interface to the MALO SER Workstation, whereby the average CFMWC user could initiate the application, select a mission, select a mission vignette, configure the selected vignette, select a tactic, configure the tactic, run the simulation, and view the results of metrics without any specialist M&S software skills.

The MALO SER Workstation’s user interface application will manage an existing COTS M&S tool, whereby the run time visualization and the analytical engine of the simulation would be permitted through the COTS M&S tool. A CFMWC user would not necessarily need to interact with the tool to initialize and configure it.

3.4 The Phase 1 SER Workstation Vignettes

The SER Workstation was to be configured for Phase 1 of the MALO project to support the established Phase 1 Experimental Plan. This plan, developed in consultation with CFMWC users, called for 1 Mission, and 3 Vignettes within that mission to be simulated in order to evaluate alternatives to the defined tactic. Additional vignettes are under consideration.

In summary, the mission/vignette/tactic experimental hierarchy includes the following elements:

- The context is one overall composition mission scenario that has been created for the purposes of Phase 1 of the MALO project. Within that scenario, 3 vignettes have been extracted, each exercising a specific tactic related to Maritime Air operations.

- Vignette 1: Anti-Submarine Warfare (ASW) by CP-140 Detection of a Nuclear Submarine. The focus of Vignette 1 is on detecting a nuclear submarine in a maritime littoral environment, using passive sonobuoys and one CP140. The SER Workstation will have one scripted tactic implemented for this vignette, with the ability to modify variables that alter the detailed behaviour of entities within that tactic.

- Vignette 2: Anti-Submarine Warfare (ASW) by Maritime Helicopter (MH) screening for detection of a nuclear submarine. The focus of Vignette 2 is on detecting/deterring a nuclear submarine in a maritime littoral environment, using passive sonobuoys and active sonar (dipping sonar) from MH. The SER Workstation will have one scripted tactic implemented for this vignette, with the ability to modify variables that alter the detailed behaviour of entities within that tactic.

- Vignette 3: Anti-Submarine Warfare (ASW) by CP-140 to conduct surface surveillance in a maritime littoral environment using current CP-140 radar and future AIMP CP-140 radar. The objective of Vignette 3 is to exercise convergent validity between the current CP-140 radar capability and the future CP-140 radar capability that will be implemented during the Aurora Incremental Military Program (AIMP). As a result, the SER Workstation will be configured with tactics, one associated with each radar suite, with the ability to modify variables that alter the detailed behaviour of entities within each tactic.

3.5 SER Workstation Functional Requirements

The high level functional requirements of the SER workstation have been summarized in this section.

At the highest level, the SER Workstation must allow the CFMWC user to:

- Initiate the system.

- Select a mission for experimentation
(only 1 mission will be entered in the Sept 2005 version of the SER Workstation).

- Select a vignette for experimentation within that mission
(only 3 vignettes will be configured in the Sept 2005 version of the SER Workstation).

- Select a tactic within the selected Vignette
(only 1 tactic will be configured for Vignette 1 and 2, with Vignette 3 having two

tactics representing alternative search strategies for the two different radar variants).

- Configure the system for that tactic
(once a tactic is select the user will be able to configure variables specific to that tactic and the systems to be employed on that tactic).

- Run the simulation.

- View the simulation animation during execution.

- Analyze and view data results.
(measures will be pre-set and specific to the tactic, allowing the user to easily request data analysis of the last simulation run).

Phase 1 of MALO TDP (development of the SER Workstation) was a time and resource constrained activity completed prior to Gate 1 in the project plan. Therefore, additional functional requirements were investigated to extend SER Functionalities with a Monte-Carlo capability. This will allow the CFMWC users to practically explore multiple options in a batch mode, which will not require any interaction with the users, and will position the SER system as an analytical tool. Example of variations in the batch mode could be the selection of a range of inputs for the start position of the enemy submarine in an anti-submarine warfare scenario.

Typical use of this capability would be as follow:

1. Select the simulation in Monte-Carlo mode.

2. Configure a Monte-Carlo simulation run in terms of ranges for the inputs variables (*e.g.* submarine speed is in the range [5:9] with a step of .5, or with a random selection) within the investigated tactic.

3. Execute the simulation in batch mode the required number of runs; Visualization or user interaction is not required at this stage as the simulation can be run in faster than real-time mode.

4. Analyze and view the comparative data results across the Monte-Carlo simulation runs.

However, it is the user responsibility to provide/program the analytical part of this activity. However the chosen simulation software for the SER system, Satellite Tool Kit (STK [3] [7]) has also an analysis module (STK Analyzer) but it has to be properly set-up, and this setting will have to be adjusted for each scenario.

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4. SER Workstation Architecture and Design

The SER workstation was designed as a stand-alone system running STK software and additional individual software packages. STK provides the necessary high end visualization, but most importantly, provides the required verified, valid and physics based modeling of entities, as well as analytical capability necessary to support the analysis of MALO tactics.

4.1 Synthetic Environment Research (SER) Workstation Architecture

A top-level SER Workstation architecture diagram is shown in **Figure 3** below. The workstation is a high end desktop, the configuration details of which can be found in the supporting document: SER Workstation Configuration. The SER workstation will utilize existing STK development environment, enhanced with additional modules and models as required for the specific Maritime Littoral environment. STK provides the necessary visualization, the physics-based modeling of entities, and analytical capability necessary to support the analysis of MALO tactics.

The SER workstation architecture and development consists of the following:

Basic STK Framework which includes the necessary programming modules (Section 4.7), and unconfigured models for standard platforms (surveillance aircraft, helicopters, ships, etc…), and sensors (Radar, sonar, etc.). The STK framework also supports the development of external models and functionality through a Socket Connect Interface that handles the image components of an external model, and Plug-In interface that handles computational data of an external model.

External Models will be purchased or developed where standard, configurable STK models do not exist (example: SAPIEM 7000 oil rig, EO/IR sensors…)

MALO Configured Models are created from STK configurable models, or custom external models. A description of the STK model layers and parameters can be found in Section 4.3. A standard set of model parameters will be created that will be used during simulation when the parameter is not an input variable that is part of a tactic being analyzed. When the experimental plan calls for a specific model parameter to be varied as an independent variable input, then the standard values are overwritten by the Tactic Configuration Interface. Output parameters from models are stored for post simulation data analysis.

Terrain and Navigational Chart databases are used by STK to enhance visual components of the simulation, as well as for interaction with models interacting with specific information within the database (*e.g.* Sonar models interacting with depth data in the terrain database).

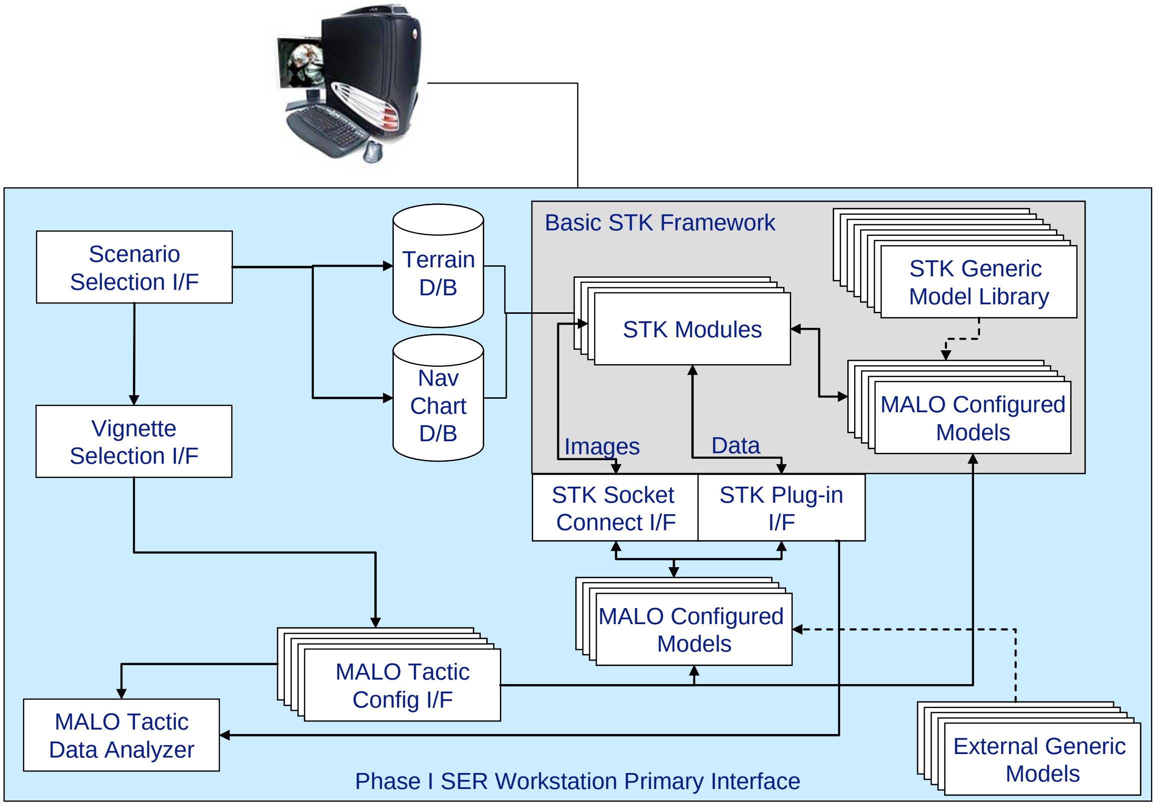

Figure 3: Synthetic Environment Research (SER) Workstation Architecture

A **Scenario Selection Interface** allows the operator to select from a set of scenarios, that which would be most appropriate to evaluate a given tactic. The Scenario establishes databases, models, and vignettes that can be used in the simulation. The Scenario Selection Interface is further described in Section 5.

The **Vignette Selection Interface** further defines the framework within which the simulation will occur, namely a specific timeframe and series of events within the overall scenario, as well as possibly enhancing the models to be utilized (*e.g.* increasing number of platforms or sensors being used). The Vignette Selection Interface is also further discussed in Section 5.

A **MALO Tactic Configuration Interface** will allow the user to configure the simulation as required by the experimental plan. A Tactical Configuration Interface will be created for each Tactic Experimental Plan providing a method of setting the independent variables of the experiment (sensor model settings, platform starting points, speed, waypoints, unit spacing, etc…) and selecting the data analysis options and formatting for the output parameters that are fixed by the experimental plan. The Tactic Configuration interface can also set up multiple executions of the simulation to collect statistical data over several runs. A more detailed overview of the MALO Tactic Modeller and Data Analyzer functionality is found in Section 4.6.

A **MALO Tactic Data Analyzer** will make use of STK data analysis modules to process and present the date received back from simulation to generate the necessary tables and charts associated with the Measures of Effectiveness and Measures of Performance.

4.2 SER Application Software Components

In order to achieve the objectives of the SER Application, and to address the required functional components, it was necessary to combine three high level software components:

1. <u>A Commercial Off The Shelf (COTS) Simulation Environment.</u>
   This simulation environment was necessary to provide the complete simulation environment needed for the SER Workstation. The environment selected for the MALO project was Satellite Tool Kit (STK) developed by AGI Inc.

2. <u>A MALO SER Workstation Software Application</u>
   This application was necessary to provide the easy to operate user interface for the CFMWC user (avoiding the need to have the user interact with the detailed interface of the COTS simulation environment), and to guide the user through the process of selecting and configuring a tactic, exercising that tactic in simulation, and reviewing the simulation run results.

3. <u>External Models of Maritime Air Assets/Sensors</u>
   These models were required to be available to the COTS simulation environment (STK) in cases where STK did not already have an available configurable model for that asset.

Further on these components could be decomposed into several key modules, shown in the list below:

1. <u>The MALO Application Layer.</u>
   The MALO Application Layer is the client in this application (client), which communicates with the server (server) which in this case is embedded STK. When the MALO application is running the client makes calls to the server, and STK services those requests.

2. <u>Embedded STK</u>
   Embedded STK is the server in this application, and is the simulation environment that provides the simulation functionality for the MALO SER Workstation. Using STK/X module the full functionality of STK is embedded and harnessed within a custom application thus turning STK into a full featured Active X component. The User can animate, view and analyze a given tactic without the need to set up numerous variables.

3. <u>STK Plug In and Socket Interfaces</u>
   STK provides a complete simulation environment, and does include some generic models for assets required for the MALO scenarios and vignettes (*e.g.* ships, aircraft). However, STK is not a generic answer to all of the services that a client application may require, and it therefore provides two different methods to interface external capability with the STK application:

a. Plug In Interface.
The plug-in interface is used for services that are not native to STK, whereby the developer can write a specific non-generic model into STK computations. Once implemented these scripts are executed during computation to integrate lookup tables, access constraints, etc., within the STK analytical framework. Plug-in scripts are the seamless extensions to the basic constraint processing.

b. Connect Interface
The Connect interface is used for services that are native to STK, whereby connect modules are utilized to interface with external applications in a client-server environment. A developer uses the library shipped with STK Connect Module that contains functions, constants and other messaging capabilities to utilize this interface.

4. MALO Data
MALO data is provided in look up tables, which are then integrated with STK using the Plug In interface. An example of look up table data required by STK is Sonobuoy signal to noise ratios which is then used to derive the probability of detection data.

5. External Models
External models include models that STK requires to run the scenario simulation. These models are encapsulated in routines whereby STK loads and interacts with that model on demand through simulation/animation. These models interface though the Connect Interface. Examples of these models for MALO Phase 1 include EO/IR and ISAR sensor models.

6. Terrain and Image Data
These geo rectified data sets are formatted and stored on the MALO SER Workstation, and are available for loading by STK when initiating a requested scenario.

The SER application decomposition shown in Figure 4 illustrates the multiples software modules and how they are connected altogether.

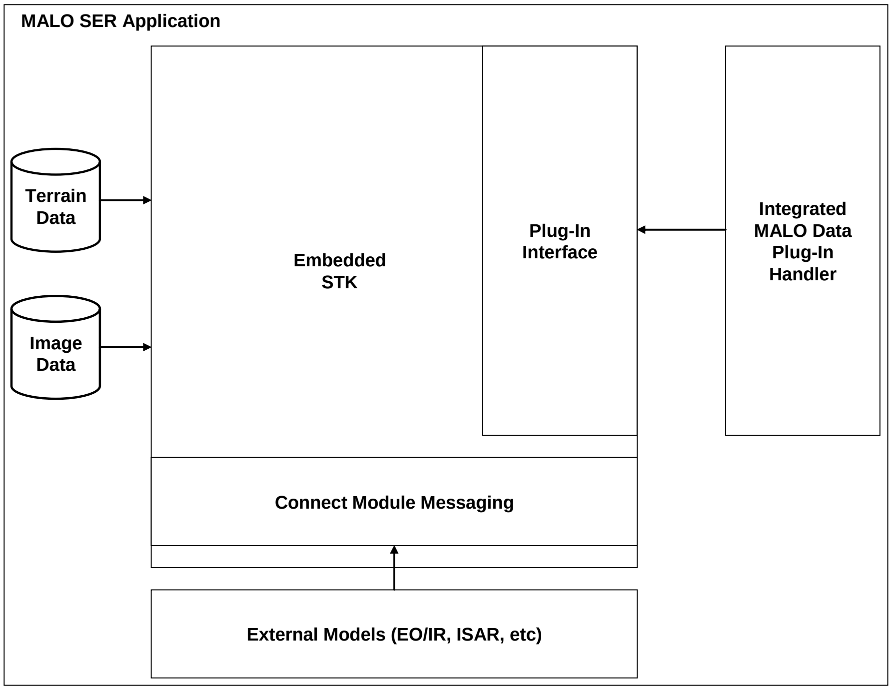

Figure 4: MALO SER Modules

4.3 STK Model layers

The construction of the modeling and simulation environment will be accomplished through the building of several unique and interlocking shells as illustrated in Figure 5.

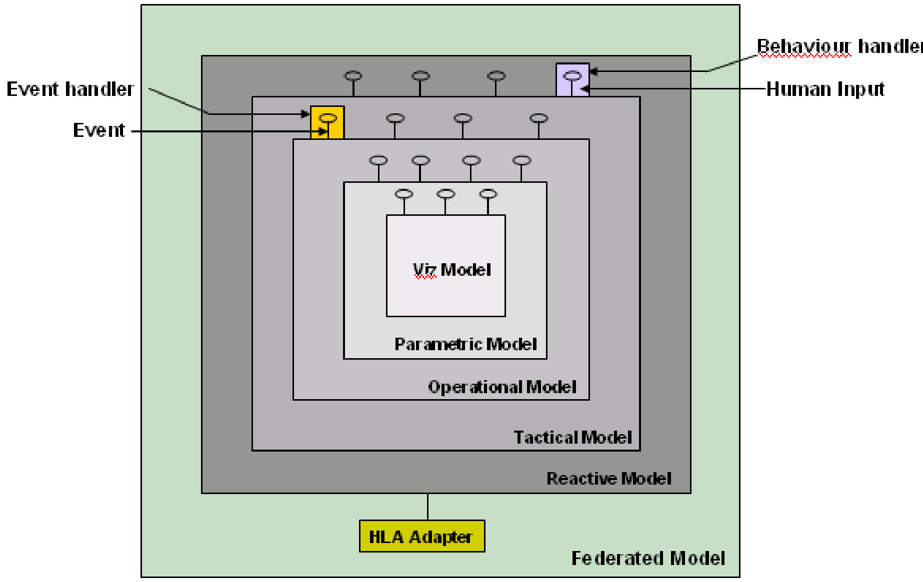

Figure 5: Modeling Shells applicable to the MALO TDP Environment

The SER workstation will only develop Visual, Parametric, Operational and Tactical model layers for stand-alone operation (light grey). The STK architecture allows for additional layers to be added to create reactive models (dark grey) as well as HLA compliant models that can be used in a distributed network simulation environment.

4.4 STK and Custom External Sensor Models

The synthetic environment will be created by generating sensor models that when implemented within the simulation will represent the capabilities associated with the sensor suites. These models will be generated through a series of default and user-defined input files that are unique to each sensor suite.

STK provides a library of generic sensor (and platform) models, which will be configured to MALO specific requirements. Within STK these models will communicate directly with the necessary STK modules that control the simulation execution.

STK handles external models through two interfaces. The *Viz* component of an externally created model communicates to the STK modules through an STK Socket Connection Interface. The Data components of an externally created model communicate to the STK module through the Plug-in interface.

4.5 MALO Primary Interface (STK Simulation Control and Execution)

In order to reduce the amount of programming required by the operator, especially at the STK and customized model configuration level, an additional software layer is

being developed to configure and control the execution of the STK simulation and data analysis. This MALO Primary interface guides the user through the steps of selecting the scenario, vignette, and tactic to be analysed, and then calls up the specific Tactic Configuration Interface to set up and execute the specific experiment, as shown in Figure 6 below.

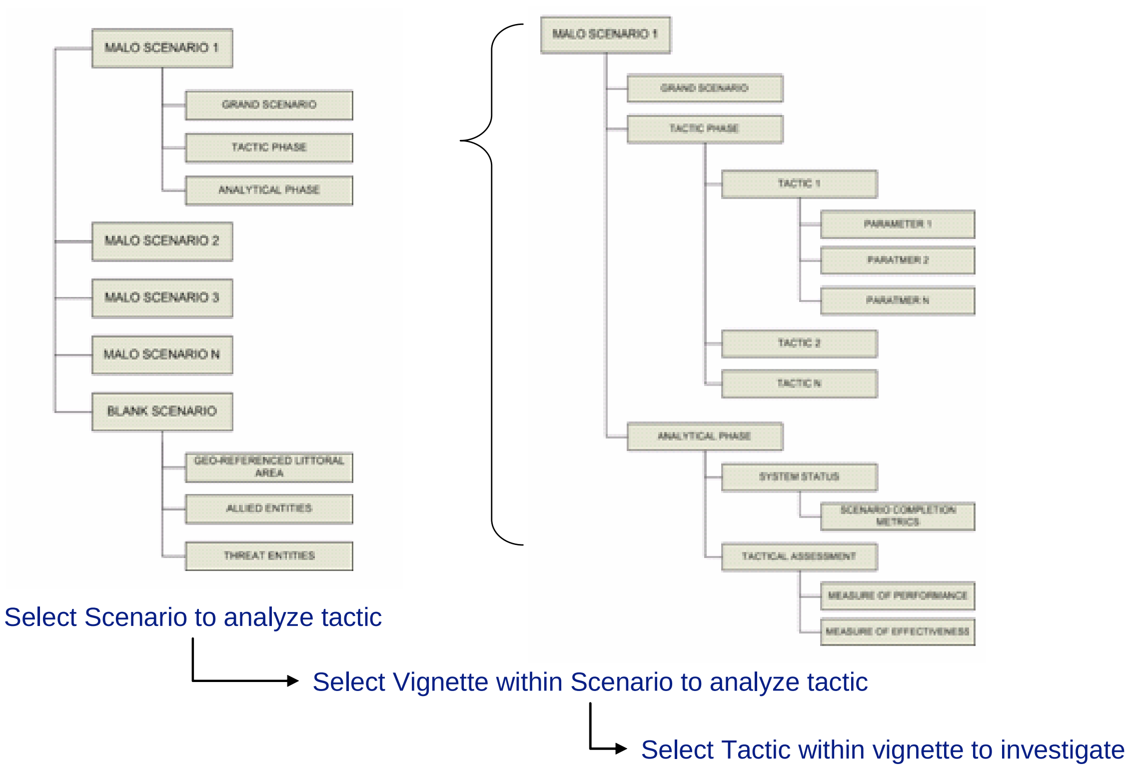

Figure 6: MALO Primary Interface Structure

The timeframe of the demonstration at the end of Phase I is such that the development of the higher level Tactical Configuration and Data Analysis modules will initially be created specific to each of the three vignettes, and the experimental plan requirements arising from the three tactics being evaluated (**Figure 8**). These three plug-ins will provide the necessary interface to the operator for its associated vignette/tactic, to program the input variables arising from the specific experimental plan, and to select the output parameters and formats for data analysis. The experience of developing these three vignette specific plug-ins will help define the process and requirements to develop a generic software layer that can be used to fully configure many vignettes and simulation experiments for a wide range of tactics.

Figure 7 shows additional detail to the MALO Primary Interface flow and capability.

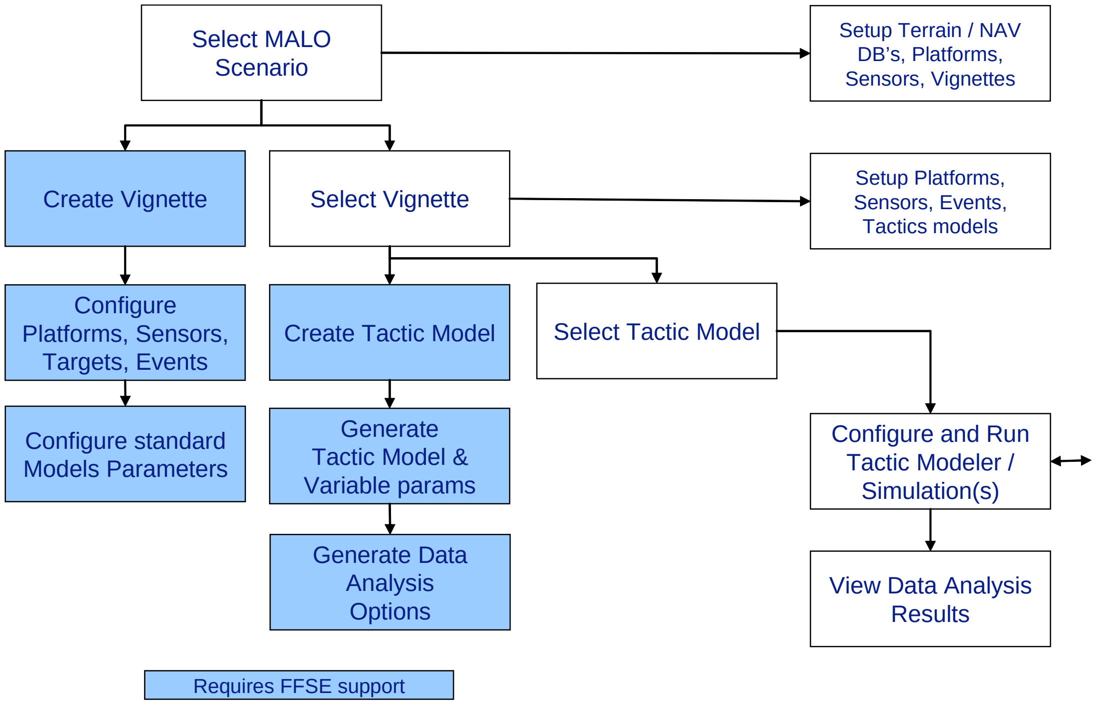

Figure 7: MALO Primary Interface Flow Chart

The MALO Primary Interface will allow for the future development of additional scenarios that can create alternate simulation environments. Scenario selection primarily defines location through a terrain database (*e.g.* East Coast of Canada, West Coast, Arctic Coast, Middle East campaigns, etc…) but also provides an initial configuration of platforms, sensors, targets, and series of events over a timeline, as well as any other visual overlays such as navigational charts. FFSE support will be required to create new scenarios.

The MALO Primary Interface will allow for the future development of additional Vignettes within the existing scenario or new scenarios. The Vignette further defines a subset of the overall scenario, wherein the number of platforms, sensors, targets, etc. are established with additional detail given to the series of events that occur. It also defines the Tactic Configuration Interfaces that are available for that Vignette, or essentially which tactical experiments can be executed within the constraints of the Vignette. Again, FFSE support will be required to create new vignettes within which to run more tactical experiments.

4.6 MALO Tactic Configuration Interface

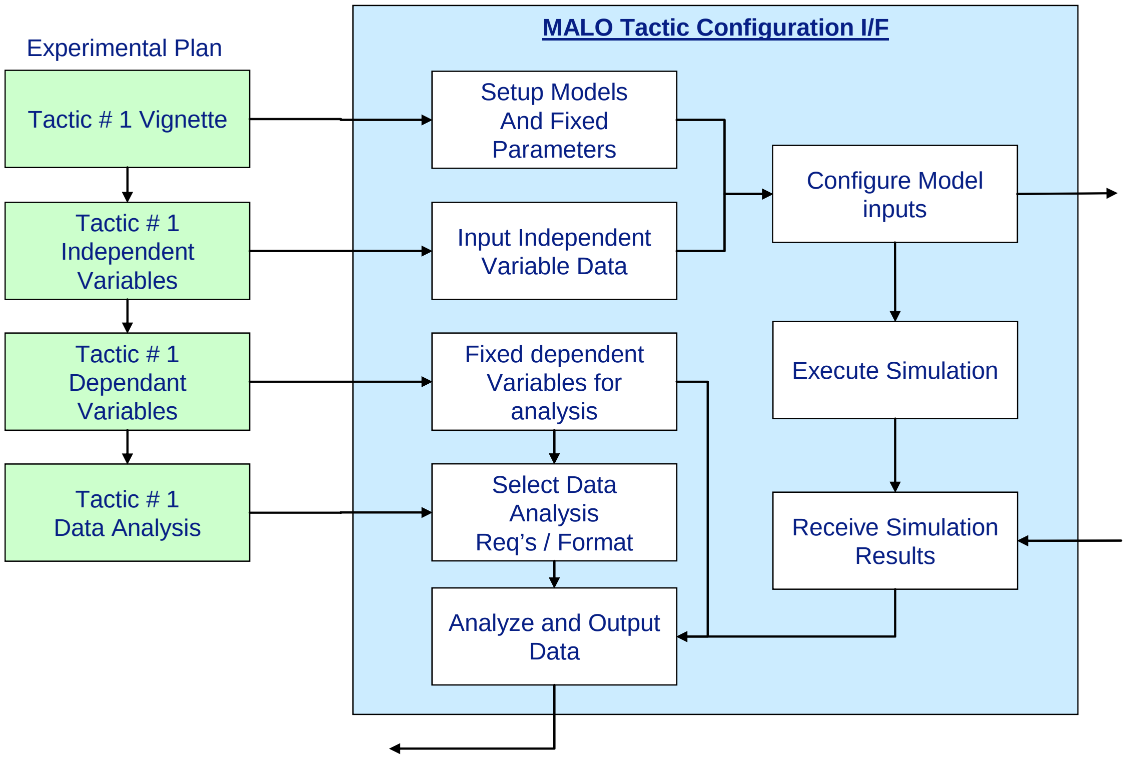

Figure 8: Phase I MALO Vignette / Tactic Modeller and Data Analyzer

In **Figure 8** the blocks that fall under the experimental plan (named tactic #1 …) represent stages in the experimental plan process, while the blocks within the MALO Tactic Configuration Interface box represent the associated functionality that will be developed to implement the experimental plan.

For each of the three tactics that will be developed for the demonstration, a specific experimental plan is being developed to exercise the tactic within a subset or vignette of the full MALO scenario. The experimental plan and vignette will define a time period, platforms, sensors, etc… that will be part of the simulation. A Tactical Configuration Interface will be created for each experiment to be run.

The Tactical Configuration block will establish all of the non-configurable units required for the simulation (*i.e.* those with standard settings that will not be varied during simulation) and establish all platforms, sensor, and target models.

The Tactical Configuration block will prompt the operator for input to the configurable parameters (independent variables) based on the experiment plan definitions. It will take those inputs and apply them to the appropriate models and simulation settings.

The Tactical Configuration block will prompt the operator to select the format of the output data to be analyzed (dependent variables) which are the measures of performance and effectiveness of the experimental plan. These output parameters are fixed by the experimental plan, but the user is provided some control over the formatting of the outputs.

The Tactical Configuration block will execute the simulation(s), logging the necessary raw data parameters. It will then process the data according to the experimental plan goals, and produce the necessary tables and charts of the analyzed data.

An experimental plan may provide a set of conditions and constraints within which a tactic is to be evaluated, either in a single run, or evaluated over multiple runs gathering statistical results. The Tactical Configuration block will provide these various conditions and constraints for simulation execution, and establish multiple runs as necessary.

In Phase 1, the simulations will be deterministic, as the set of entities that is represented within each simulation will be scripted in the STK environment and no external code related to entity behaviour will be included. Within this environment it will be possible to interject random behaviour into the simulation in two ways: pseudo-random variable data, and modification to initial conditions.

In the first case, Monte-Carlo analyses will be conducted during the initial stages of tactical assessment to determine whether there is sufficient value associated with investigating a particular tactic within the STK stand-alone system. To do this, these initial analyses will assign pseudo-random values from within a pre-defined range for the particular variable (sensor parameters, entity position, speed, headings, etc…) to determine the overall effect of the variable on outcome of the tactic.

In the second case, values associated with the initial conditions and detection probabilities can be manipulated in the simulations manually, or through the use of scripts, to observe the overall impact on the outcome of the tactic under investigation.

4.7 Synthetic Environment Research (SER) Workstation Elements

The Stand Alone Synthetic Environment design will utilize existing STK development environment, enhanced with additional modules and models as required for the specific Maritime Littoral environment (see Table 1).

The STK Modules / Models Deficiency list in Table 2 identifies the additional STK modules to be purchased, and models that will need to be developed. The following summarizes these requirements:

STK Modules owned by FFSE	**Modules:** • STK Pro

prior to the MALO TDP	• STK Connect • STK Advanced VO • STK Coverage • STK Communications • STK Terrain • STK Radar
STK Modules (needed for MALO TDP implementation)	**Description**
1. STK/X	Makes STK embeddable in custom, proprietary applications. Provides flexibility to integrate STK with other third party applications.
2. STK Flight Control	Intelligence preparation of the battle space • Mission planning • Mission rehearsal and training • Situational Awareness • Situational Analysis
3. STK Attitude	STK/Attitude allows constructing attitude profiles to align the vehicle's body axes with any axes or vector either predefined or built with the STK Vector Geometry Tool, *e.g.*, MH or CP-140 can be aligned with Ground Task Force for receiving Command and Control. Additionally, multiple attitude segments may be threaded together over the vehicle ephemeris to represent multiple maneuver sequences or mission modes. Segments may be either coordinate based, targeted, or file-driven. User-defined slew segments can be used to govern the transition between individual attitude modes. • Multi-segment attitude: Allows input of different segments for different attitude profiles. Most useful for missiles. One section can be "Inertially fixed", then at some time later, change to "precessing spin", etc. • Attitude Sphere: Project this sphere around vehicles. Display vectors and sensors on this sphere. Provides a grid around the object that allows visualization of elevation angles around the vehicle. • Attitude Coverage: Displays STK/Coverage graphics around the vehicle. This is similar to the Attitude Sphere, but allows display of color coded Figures Of Merit (FOM) calculated by STK/Coverage around the vehicle. • Attitude Reference: For importing attitude data into STK relative to a non-standard set of Axes, then

	STK/Attitude allows you to reference the Axis that is created in the Vector Geometry Tool (VGT). VGT comes with STK/Pro
4. STK Author	Easily packages STK scenario for widespread distribution Shares STK analyses without compromising original analyses Incorporate analyses from all licensed STK modules Integrate stored viewpoints, camera paths, and data displays Provide a means for AGI Viewer to embed STK output into PowerPoint slides or HTML web pages. Enable movie making.
5. STK Analyzer	This module is beneficial for MOE, MOP and MOU identification and generation.
6. STK High Resolution Earth Imagery	Need Marine's Bathymetric model of the Planet Earth/Face of the Earth
Optional	
1. STK Missile and Interceptor Flight Tool	High Fidelity Missile and Interceptor trajectory generation. This includes: • flight control (options include maximum range flights, specific launch and target points, and lofted trajectories) • boost-phase modeling • object free-flight modeling • re-entry flight over a user-controlled trajectory • payload deployment modeling Notes from talking to AGI: 1. Missile Flight Tool (MFT) does not model Air to Air cruise missile. 2. MFT models Surface to Surface and Surface to Air ballistic missile. 3. MFT takes into account the atmospheric model. 3. MFT is just a stationary Launching platform. 4. IFT performs a Air to Surface intercepts 5. It can work with STK's Missile object.
2. STK Advanced Radar Environment	• Dependent on radar to earth geometry and terrain altitude • Overland/overwater and statistical variation • Target S/I ratio and POD based on deterministic clutter • Analyze radar sensitivity to geometries, radar parameters, antenna and targets • Allows the user to model pulse Doppler radars and incorporates important characteristics including clutter, noise, system parameters, radar cross section and antenna type while generating reports and graphs of the radar performance

Table 1: FFSE owned STK Modules prior to the MALO TDP

	Description
To be noted: 1. *Some models can be built in-house and some are "suggested" as to be out-sourced. Disclaimer – Outsourcing companies suggested are purely based on research done and their previous contracts with DRDC and DND.* 2. *Besides the following Models, MALO TPD needs a lot of other models, but those have been implemented for ALIX and CapDEM TD and can just be reused.*	
1. Saipem 7000	Procured/outsourced. FFSE shall do the parametric configuration.
2. HALE UAV	Develop at FFSE
3. Halifax Class – Multi Role Patrol frigates	Develop at FFSE
4. Area Air Defense Destroyer Ship	Develop at FFSE
5. Auxiliary Oil Replenishment Ship	Develop at FFSE
6. Long Range Patrol Replenishment	Develop at FFSE
7. Patrol Boats	Develop at FFSE
8. Sonars	Parametric Configuration can be done at FFSE.
9. Sonobuoys	Flight Line Control Systems in US is specialized in Sonar and Sonobuoy technology.
10. EO/IR Sensors	DRDC Valcartier.
11. ISAR (Inverse SAR)	DRDC Ottawa.

Table 2: Models Deficiency List for the MALO TDP

	Description.
Visual Studio.NET	S/W development tool for creating external models as plug-ins to the STK environment.
Global Mapper	Need this tool for clipping aerial images of any Area of Interest and to overlay the image on to a digital terrain data, before importing it into STK for visualization. Costs around US$ 450.00

Table 3: Tools to Complement MALO TDP Scenario Development

	Description
Detection:	
1. Ground Moving Target Indicator (GMTI)	GMTI algorithm can be developed internally at FFSE and parts of it can be borrowed from RAST section
2. Inverse Synthetic Aperture Radar (ISAR)	ISAR –Vantage Point Inc, a company in Ottawa is specialized in ISAR technology.
3. Magnetic Anomaly Detection (MAD)	Magnetic Anomaly Detection (MAD) – pending investigation/research
4. Underwater Sonar Detection	Underwater Sonar Detection –Flight Line Control Systems in US is specialized in Sonar and Sonobuoy technology.
5. Infra Red Detection	InfraRed Detection – Mission Research Center in New Hampshire is specialized ion EO/IR sensor technology.
6. Weather Detection for MH (need STK's Adv Radar Environment)	Weather detection can be developed in collaboration with AGI using their Advanced radar Environment Module.
SAR Imaging	Vantage Point Inc, an Ottawa based company is specialized in SAR related work.
Target Classification	Algorithm can be borrowed from RAST section
Target Identification	Algorithm can be borrowed from RAST section
Chaff and Fare release for self defense	It can be developed in collaboration with AGI.

Table 4: Algorithms Needed for Medium and High Fidelity MALO Scenario

5. SER Application Design

This section outlines the high level design of the SER Application, using the architecture described in Section 4.1. It also provides a detailed description of the workflow processes that will be followed by both a SER operator from the CFMWC, or by a SER "super-user", which will likely be a FFSE personnel.

5.1 SER Application Software Design (High Level)

The SER Application software design is illustrated at a high level in **Figure 9**.

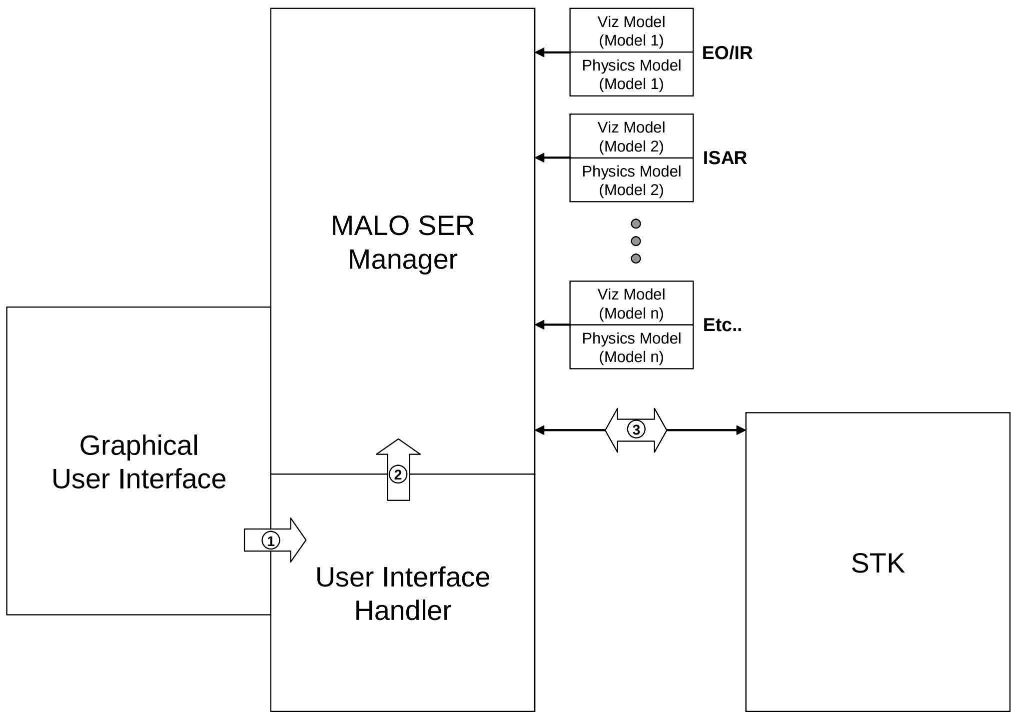

Figure 9: High Level SER Application Design

There are five main software modules illustrated in **Figure 9**, with main flow of activity across those modules indicated (steps 1 through 3). These modules include:

1. <u>MALO SER Graphical User Interface</u>
   This software module will include the graphical user interface to the MALO SER Application. This will be the interface that the CFMWC user interacts with at the SER Workstation. The interface will include the forms, menus, editable fields, selectable objects etc. in support of the user's task flow through the application. This module will be developed using Visual Studio.Net.

2. MALO SER User Interface Handler
   This software module will receive the calls from the MALO Graphical User Interface (Step 1 in **Figure 9**), and process the requests and pass them to the MALO SER Manager (Step 2 in **Figure 9**). This module will be developed either in VB.NET or in C#.

3. MALO SER Manager
   This software module is the main engine of the stand alone SER Workstation application. This module initializes the connect modules, initializes the connection with STK, loads the scenario parameters, loads the vignette parameters, creates (using parameter inputs from the GUI) and loads the tactic pertinent models (which are either external or native to STK), and provides the tactic pertinent functions and algorithms. Step 3 in **Figure 9** illustrates the ongoing bi-directional communication between the MALO SER Manager and the STK application. This module will be developed either in VB.NET or in C#.

4. External Models
   These external models will be available in a routine that is not part of the MALO SER Manager, whereby the SER Manager calls that model and loads functionality on demand based on the scenario. The exact format of these external routines will be dependent on ongoing discussions with the sources of the models (*e.g.* DRDC Valcartier), but might include C, a DLL, or a binary file format.

5. STK Application
   The STK application is the embedded COTS simulation application selected for the MALO SER Workstation.

5.2 SER Application User Task Flow

There are two different types of users of the SER Workstation, including:

1. The CFMWC User, who is the primary user of the SER Application. This user is assumed to be an operational military user, with basic computer interaction skills, but with no advanced skills in simulation application operation or model or simulation application development.

2. The FFSE User, who is the user responsible for configuring the SER Application. This user is assumed to have a background in modeling and simulation, but with intermediate to advanced skills in simulation application operation or model or simulation application development.

5.2.1 CFMWC User Task Flow

The task flow for the CFMWC user is illustrated in Figure 10. This figure indicates an optional task flow for the conduct of Monte-Carlo based simulation runs which is not expected to be implemented for the September 2005 initial delivery of the SER Workstation, but is considered in the design for future implementation.

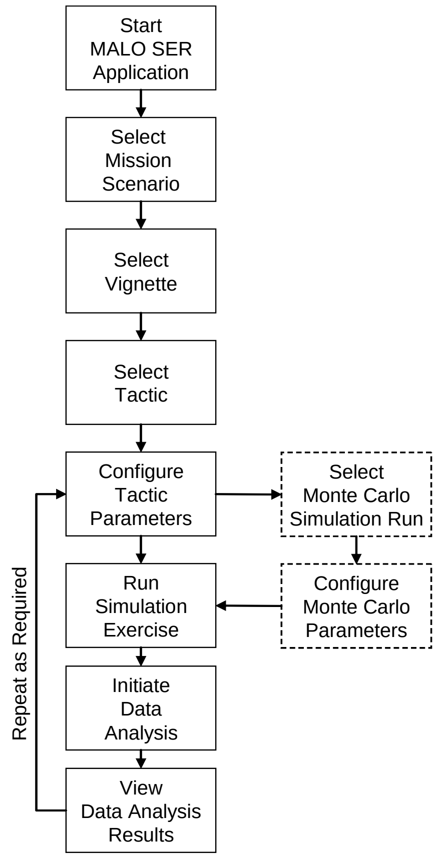

Figure 10: CFMWC User Task Flow

5.2.2 FFSE User Task Flow

The high level task flow of the FFSE User is illustrated in **Figure 11**. This task flow assumes FFSE interface with a CFMWC centre user to configure the SER Workstation for specific missions, vignettes, and tactics, and with specific Measures of Performance and Effectiveness for that experimental series. This task flow results in the SER Workstation being properly configured for repeated use by the CFMWC user, operating with the task flow outlined in Section 5.2.1.

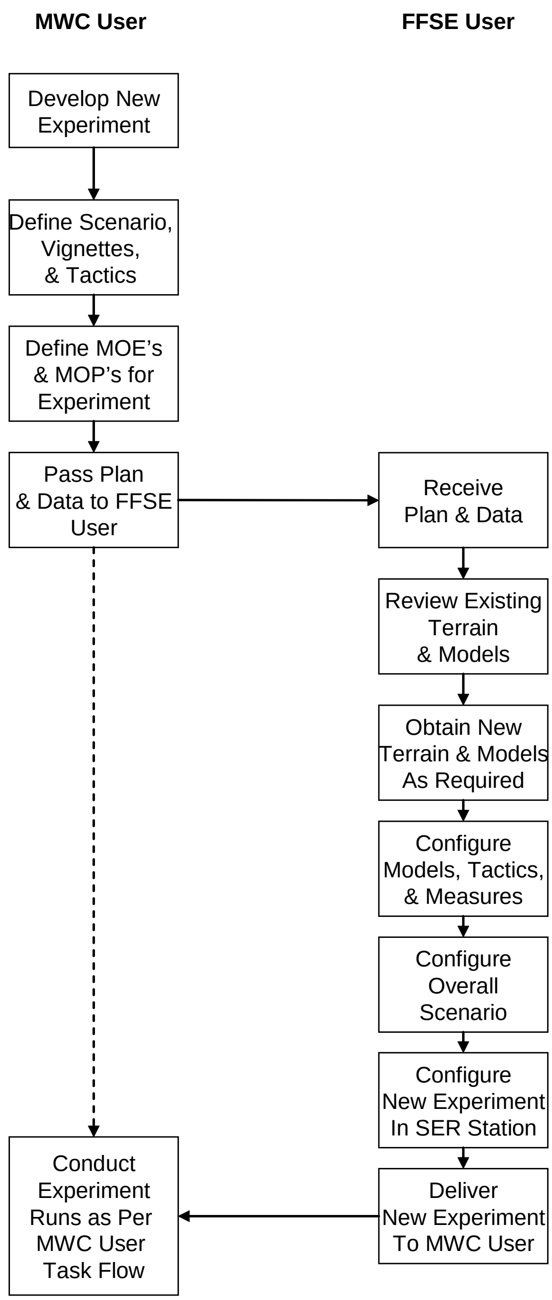

Figure 11: FFSE User Task Flow

5.3 SER Application User Interface Design

The CFMWC User requires a Graphical User Interface to support their task flow. A conceptual design has been documented to illustrate the "intent" of the graphical

interface design, as illustrated in Figure 12. This design is not the final one; it is simply the conceptual intent of the GUI wizard that will step the user through the M&S based evaluation of tactic variations without having to interact in detail with the base simulation application (STK).

The primary steps in this GUI design story board map to the steps in the CFMWC user's task flow, and includes the following elements (numbers in this list match numbers in Figure 12):

1. Initiate Application, using icon on desktop.
2. Selection Mission
3. Select Vignette
4. Select Tactic
5. Configure Tactic Parameters
6. Run Simulation
7. View Simulation Execution
8. Run Data Analysis
9. View Data Analysis Results

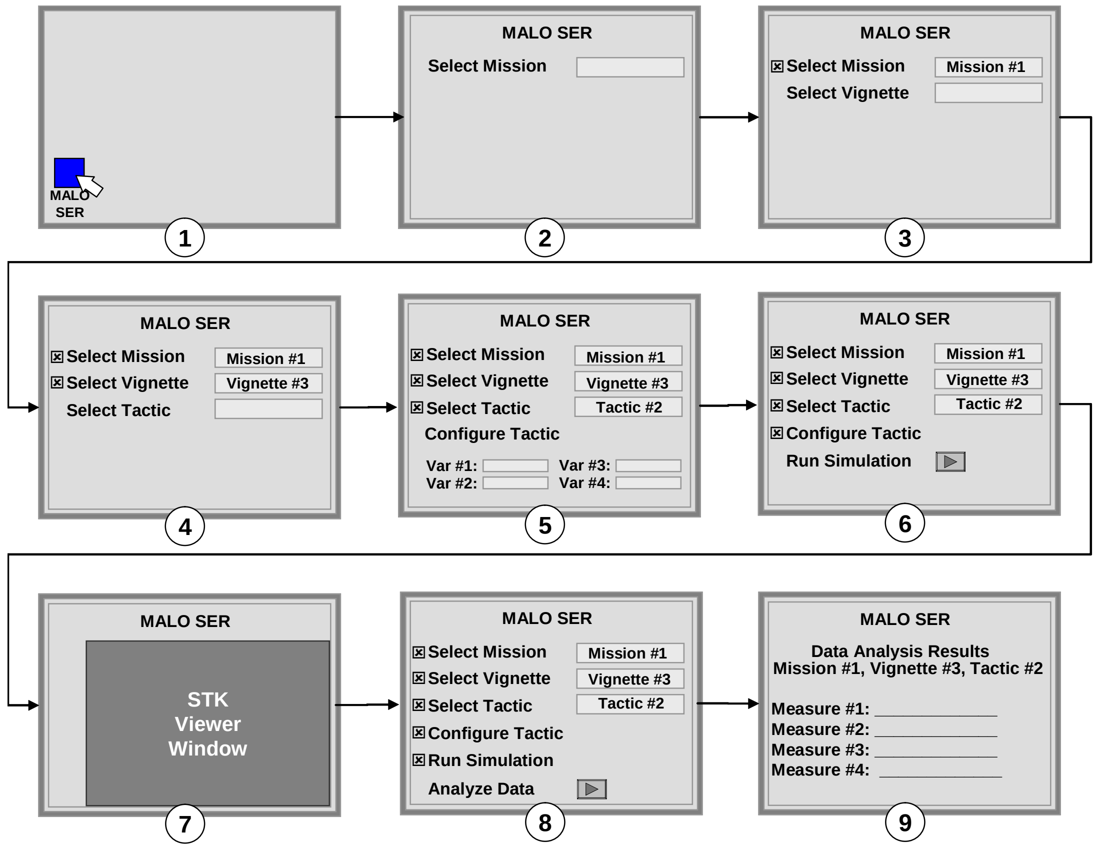

Figure 12: MALO SER Application GUI Conceptual Design Storyboard

6. Discussion and Conclusion

Starting in March 2005 under FFSE's lead, the Maritime Air-Littoral Operations TDP was assigned new objectives that are a superset of the initial objectives, and was organised in a four phased incremental development process.

During phase one of the MALO TDP, the overall hypothesis that M&S can be used to develop and assess Maritime Air tactics was tested and positively confirmed through the demonstration of the execution of experiments in the SER workstation. More specifically, phase one had for target the development, the demonstration and the transition and exploitation to the TDP client, the CFMWC, of a standalone physics-based credible SE simulation capability as described in this document, the SER system.

The selection of the STK software as the target environment or the core simulation engine behind the SER system resulted in a very powerful concept not only for the animation side, which is crucial for the user's situational awareness perspective of the battlefield, and for the simulation aspects of the implemented scenarios, but also, and most importantly, for the analytical side of this solution. Fundamentally, it resulted in a credible environment that integrated assets from space, air, ground, surface and sub-surface of the water.

A prototype SER was developed and successfully demonstrated through operational scenarios built with the client. Further, the prototype SER was capable at the same time to deliver a baseline capability to the CFMWC to explore variations to tactics that are modeled within the environment. The TDP obtained the client support and concurrence with the chosen technology. A CD&E SER system is to be extended and procured with such extensions to the existing SER system, and additional functionalities, like the Monte-Carlo capability for statistical validation.

Subsequent phases of the project will develop a distributed HLA based simulation, with greater focus on the models and space resolution and fidelity, and most importantly on the entities' behaviour, either through CGF or with humans in the loop. However, the two systems will both be part of the same experimental strategy for tactics evaluation. The first, the SER, is used for the rapid selection of the "Winning" tactics or a "triage" tool, and the second, the MSEAS, is used for an advanced investigation of these selected tactics, in a "Higher Fidelity" simulation environment, which will eventually allow for the integration of "high-end" HITL simulators, as a submarine or/and a maritime helicopter simulator, etc.

Finally, some innovations were achieved during the first phase of the MALO TDP, essentially dealing with the original approach that was adopted for the conduct of the project. This incremental strategy for the execution of the project, which combines two different capabilities for the same goal, has proven to be a successful and innovative approach in the development of a simulation system. It resulted in several benefits from which we are listed below:

- The delivery, at an early stage of the project, of a simulation capability without having to wait the development of HLA simulations;

- The use of the SER in better understanding how to develop and refine the system and modeling requirements for the next stage, higher fidelity, capability;

- The availability of a low cost, flexible simulation capability to complement a more rigorous, higher-fidelity system;

- The match between the tactics development process, which itself is incremental, and the planned stages of simulation fidelity. The SER can be employed for triage for users to quickly select only a few tactics within hundreds that are proposed, or quickly build and test a new concept, before moving to a more extensive evaluation of the tactic;

- The emergence of an experimental process consisting of three steps that make effective use of both simulation and live resources, *i.e.*:

    1. Stand-alone (fast) constructive simulation, followed by,

    2. HLA-based synthetic environments that may include humans in the loop, followed by,

    3. Live trials, as required.

- Finally, the SER system can provide a documented heritage to models used at later stages (*e.g.* the low fidelity HLA simulation), which stresses the incremental character of the adopted development process for the TDP.

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The Maritime Air Littoral Operations (MALO) Technology Demonstration Program (TDP) was undertaken by the Future Forces Synthetic Environment (FFSE) at Defence Research and Development Canada (DRDC) Ottawa to develop a modeling and simulation (M&S) based experimental environment to support the development and evaluation of maritime air operational tactics, doctrine and new concepts. The hypothesis being tested is that simulation can be used to evaluate Maritime Air tactics.

A prototype for a Stand-Alone Physics-based Simulation Capability, termed the Synthetic Environment Research (SER) workstation, was designed and built in Phase one of the MALO TDP. The prototype was designed to support rapid experimentation within pre-configured operational scenarios and tactics alternatives, and to be employed by personnel at the CF Maritime Warfare Center during the early stages of concept development and experimentation. The SER consists of a Commercial-Off-The-Shelf (COTS) tool, the Satellite Took Kit from Analytical Graphics Inc., embedded within a MALO – specific user application layer and interface that leads the operator through the experimental process of building scenarios to be investigated, modifying tactic variables, running and re-running a simulation, viewing data on programmed metrics, and visualizing the scenario execution.

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